the ground, as they must have been misinformed on those particulars, which can all be disproved.

HENRY ROBERTSON, Engineer."

In examination, the witness objected to the principle of the bridge, but thought strength might be made to obviate that principle. Had tested the bridge by taking three engines over it before the opening of the line, but was not aware if the supports had been removed from under the bridge at that time!

Captain Simmons, inspector of railways, having stated that he had been appointed by the Government, in conjunction with Mr. Walker, C.E., to inspect the bridge at Chester, and to inquire into the cause of the accident, proceeded to read their joint report. According to the *Chester Courant*, it was an elaborate and able document, but was so cautiously guarded by reasonings upon probabilities and conflicting engineering opinions, that the decision of the Government inspectors was not very positively pronounced. "Their concluding inferences, however, were, that the first fracture was made in the *centre of the girder*, that the girder of itself was too weak to support the weights usually passing over it, and that *the principle of the construction of the bridge was objectionable.*"

Below we give some portions of the report, which have since reached us.*

The coroner then summed up, and the jury returned a verdict, of which the following is the close:—

"We are further unanimously of opinion, that the aforesaid girder did not break from any lateral blow of the engine, tender, carriage, or van, or from any fault or defect in the masonry of the piers or abutments; but from its being made of a strength insufficient to bear the pressure of quick trains passing over it.

We feel, that the eleven remaining girders having been cast from the same pattern, and of the same strength, are equally weak, and consequently equally dangerous for quick or passenger trains, as was the broken one.

We consider we should not be doing our duty towards the public, if we separated without expressing our unanimous opinion, that no girder bridge of so brittle and treacherous a metal as cast iron alone, even though trussed with *wrought* iron rods, is safe for quick or passenger trains. And we have it in evidence before us, that there are upwards of one hundred bridges similar, in principle and form, to the late one over the river Dee, either in use, or in course of being constructed, on various lines of railway. We consider all these unsafe, more or less so, in proportion to the span; still all unsafe.

We, therefore, call upon her Majesty's Government, as guardians of the public safety, to institute such an inquiry into the merits or demerits of these bridges, as shall either condemn the principle, or establish their safety to such a degree, that passengers may rest fully satisfied there is no danger; although they deflect from 1½ to 5 inches."

On the effect of this deflection an architect of standing, who signs himself "J. W." has forwarded to us the following remark:—

"I am dissatisfied with the opinions of the eminent men who have expressed their sentiments relative to the disaster which has occurred, because none of them have attributed the failure of the iron to the disintegration arising from the repeated deflexures of the girder, which was at length fractured. It appears from the evidence, that this iron beam bent frequently when trains passed over it; now, as cast-iron is granular not fibrous, or very little so, every time it is deflected it loses a portion of its adhesive constitution, wherefore a repetition of flexures ultimately destroys its cohesion: the reverse takes place with wrought-iron of good fabric, if it is suffered to recover its first position. When wrought-iron or timber beams fail, they do so from imposition of too great dead weight."

We will close our article with a communication from our correspondent on the spot, which will be read with interest:—

At the middle fracture of the rib the section of the body is 2 in., the upper flange 7 in. by 1½, the lower flange 24 in. by 2½, and the depth 3 ft. 9 in. the width of the space being 98 ft. The breaking weight of this rib, according to Hodgkinson's formula, is calculated to be 62 tons on the centre, which is equivalent to 124 tons distributed over the rib, and to 248 tons equally distributed over the bay or platform. The weight of the roadway appears to be as follows:—

| | Tons. |
|---|---|
| Weight of girder and rods, 31 tons by 2.... | 62 |
| 4 lines of rail (70lbs. to the yard) ..... | 12½ |
| 60 chairs (¼cwt. each) ..... | 1½ |
| Ballast 22 cube yards (6 in. deep), 25 cwt. to the yard ..... | 27½ |
| 13 tie rods, 13 lbs. to the foot (162 lbs. each) | 1 |
| Timber, oak, 180 cube ft. (73 lbs. to the ft.) | 6 |
| ——— pine, 400 cube ft. (41 lbs. to the ft.) | 7½ |
| | 118 |
| To which is to be added, the 2 coats of arms 10 cwt. each, on the rib that failed ..... | 1 |
| | Tons 119 |

So if 119 tons is deducted from 248, it leaves the net breaking weight 129 tons: this divided by 3, the system usually adopted by engineers, gives 43 tons, the weight it may be safely loaded with. Mr. Fairbairn, in a recent communication to the Institute of Civil Engineers, recommends ⅓, which would reduce it to 32½ tons, and this is a very safe calculation, as the deflection of cast iron commences at one-fourth its breaking weight.

It has been stated in evidence by Mr. Lee, Civil Engineer, that 100 tons had been placed upon the bridge; and Mr. Stephenson states, that the greatest weight it may be loaded with is 86 tons: so that in one instance nearly the breaking weight has been upon the bridge, and it is at all times liable to be loaded with a weight double what it ought to be, and which would permanently injure the structure.

The line is 5 inches nearer the south side of the bay than the south side, so this circumstance would throw an additional weight upon the side where the rib is broken, in addition to the 2 coats of arms previously mentioned.

We also find upon trial, that the ribs are not vertical, one or two inclining as much as 1½ in. in the depth of the girder; this would have a tendency to weaken them, because cast iron will not bear that pressure inclined, as it will in a vertical position, so that the further you incline the ribs, the weaker will they become, until by turning them over on their sides, they will break with their own weight.

Mr. Stephenson stated, he could camber the ribs by means of bolts passed through a plate at the angular points of suspension, and attached to the tension bars: an allowance has been made in the joint of the rib for that purpose, but it seems to have failed in practice, as the ribs are now level.

The tension-bars, as arranged on this bridge, seem of little service, because the object of trussing is to strengthen the weakest point, which, undoubtedly, is the centre, so that a beam should have but one angular point of suspension. The principle has failed in Manchester, at Mr. Gray's cotton mill, and the reason stated by Mr. Fairbairn was, that it allowed the breaking weight to be arrived at before the tension-bar came into action.*

Besides, the tension-bars are attached to the girder, and, in consequence of not being confined to any fixed point on the piers or abutment independent of the girder, they have deflected as the girder deflected with the weight passing over, varying from 2½ in. to 5½ in., as proved by respectable witnesses.

In calculating the strength of the tension-bars, if in action, which is not the case in this bridge, the following results are arrived at:—An inch bar of iron will suspend from 27 tons to 30 tons before it breaks; it will bear from 15 tons to 16 tons before it begins to stretch, or extend in length; and the calculation of Mr. Telford, in his experiments for suspension-bridges, was to allow 4 tons for every square inch of iron, instead of eight, as assumed by Mr. Stephenson; so that, multiplying 3 in. by 6 in., the size of the suspending bars, and that by 4, gives 72 tons for one chain, or 144 tons for one rib, or 288 tons for the bay.

But a deduction most be made from this calculation on account of the difficulty in fitting together so many pieces of ironwork with that nicety and accuracy, so that every part should discharge its due share of duty.

An iron wall plate would have proved beneficial for bridges of this character, as it would distribute the weight equally over the breadth of the piers and abutments, instead of having the entire weight of the pier at four small fixed points a considerable distance asunder; besides, it would have prevented the stonework from falling when the rib fell.

The bridge was not well braced together; it is tied together transversely by thirteen ties, 4 in. by 1 in.: these are let into dove-tailed cast iron sockets, 3 in. long on the edge of the flange of the girder. The timber braces, supporting the roadway, are 4 ft. in extent, and 10 in. by 9 in. with a similar bearing upon the flange of the middle section of the rib, so that this will account for the buckling in of the top flanges of the ribs, and the spreading out of the lower flanges when weights pass over it. Besides, there is no diagonal bracing. This seems very important to check oscillation and vibration (which are very perceptible in this bridge), the most destructive agent of cast-iron.

Cast-iron is a material of such a doubtful character for bridges (particularly of large span), that we desire to see wrought-iron substituted for it; there would be no difficulty in rolling beams of the size and dimensions required.

The system of testing iron girders in foundries is to be objected to, as adopted at the bridge, because castings are liable to accident and injury in carriage, fitting, and erection. The French system of having them tested by government officers when in their place is to be preferred.

But even supposing this accident arose from a side blow, as assumed by some eminent engineers, without a tittle of evidence to support that hypothesis, it still amounts to this, that the bridge is not strong enough. A bridge that fails either from vertical pressure or a side blow, occasioned by the regular traffic, to which it is at all times liable, must be to all intents and purposes too weak; and neither the reasoning of Plato nor the eloquence of Demosthenes will convince the public to the contrary; and the sooner the bridge is taken down or strengthened, or protected from these

* The following is from their report:—

"That the bridge was of sufficient strength if the cast and wrought iron be supposed to act together, each taking its equal proportion of the strain.

That there is great difficulty in insuring the joint action, and that if this is a part of the principle of the bridge, we do not approve of it.

That neither the wrought nor the cast iron, taken separately, was sufficient for perfect stability, and that to have insured this, the cast-iron girders alone should have been of sufficient strength to carry the whole weight, with an ample allowance for the various circumstances some of them peculiar to this bridge which we have explained.

That, with the exception of the bends or warps in the top flanges, the castings are of good quality. That the wrought-iron is also of good quality.

That the strength of the piers and abutments is good, and in no way contributed to the failure.

We now come to the question, what was the immediate cause of the accident? As the bridge has carried as great, or greater, loads before, the supposition that there was something peculiar in this case, as the end of a rail having projected from the straight line, and been struck by the engine, or the tender having got off the line and struck the girder laterally, is not improbable. The engineers who were called by the railway company considered that the breaking of one leaf of the wrought-iron that was next the tender, the piece that was struck out of the girder, and the damage to the abutment wall, are all proof of the fact that the accident was caused by the tender having got off the line, and broke the girder by a heavy lateral blow. We refer to the evidence of Mr. Robert Stephenson, Mr. Locke, Mr. Vignoles, and Mr. Grouch, who were also of opinion that the strength of the girder was sufficient. As to this latter point, we have already stated the principles upon which alone this conclusion could have been arrived at, and our own opinion. As to the tender, or the carriage immediately behind it, having got off the railway and damaged the abutment walls, there is no doubt; and if the tender struck the side of the girder, when the latter was under great strain, a fracture was the probable consequence. This is on the presumption of the tender having got off the line from some other cause than the breaking of the girder.

Our own decided opinion, formed from the statement we have made as to the strength of the girder, and from the position in which the broken pieces were found, the two halves being each in a straight line, or nearly so, but at an angle with one another, is that the first fracture took place in the centre of the girder, and not at the end, which rested on the abutment.

Having reference to other cases, it is proper to state that Mr. Robert Stephenson stated in his evidence that he had erected a number of bridges on the same principle as this, and that this was the first failure. We have not examined these bridges; they are stated to be all of a less span than the Chester bridge, but that the dimensions of the parts are proportionally less, and it may perhaps be argued, from the above numerous examples, and the opinions of the eminent engineers, opposed by this one failure, that we are mistaken in considering the weakness of the girder to be the cause of the failure in the present case, and unnecessarily cautious in the opposition we entertained, and have expressed, as to the principle of this bridge and its security, but, as we entertain these opinions very decidedly, it is our duty by no means an agreeable one) to express them."

* There was a model exhibited of the girder at the inquest, demonstrating most forcibly the fallacy of the system of trussing adopted at this bridge. When the model was placed in the position of the girder, it deflected considerably (some 2 or 3 inches), with 28 lbs. suspended from the centre; but when turned upside down, it bore the weight with scarcely any deflection, and with the accidental weight of a chain upon it.

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